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Loads and Stress Analysis Cycle Automation in the Automotive Suspension Development Process

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Abstract

The article describes the use of the Multi-Body Dynamics (MBD) models, the Finite Element Analysis (FEA) and the CAD-modelling process in the automotive suspension development. Automation of maximum quasi-static loads calculation with the automatic two-way geometry update between MBD/CAD-models and automatic load transfer to the finite element analysis allows performing numerous analysis of suspension during development without significant time consumption, and, hence, provides an increased accuracy and reliability of stress analysis results.

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Keywords: Suspension; Multi-body dynamics; Finite element analysis; Loads analysis;

1. Introduction

Modern process of automotive suspension development include Multi-Body Dynamic (MBD) analysis, Finite Element Analysis (FEA) and CAD-model building. This paper shows that automation of maximum quasi-static loads calculation (using two-way connected MBD and CAD-model) and automatic loads transfer to FEA allows saving time costs for full geometry-loads-stress evaluation cycle. This enables to place the MBD-model development before (or, at least, at the same time with) CAD-model development, increasing number of analysis cycles without significant time consumption.

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2. Automotive suspension virtual prototype development stages

Traditional suspension development process consists of following stages:

1. Preliminary analysis of suspension packaging into the vehicle. Vehicle integral performance indicators estimation using simple analytic calculations [1,2].
2. Suspension parts 3d-modelling and packaging into whole vehicle 3d-model.
3. Suspension MBD-modeling: links and joints specifying, kinematic analysis and maximum quasi-static force factors calculations.
4. Intermediate finite element analysis and final approval of suspension parts strength.
5. 2d-drawings and final 3d models formalization.

Specified above stages are shown at fig. 1. as an example process for double wishbone independent suspension.

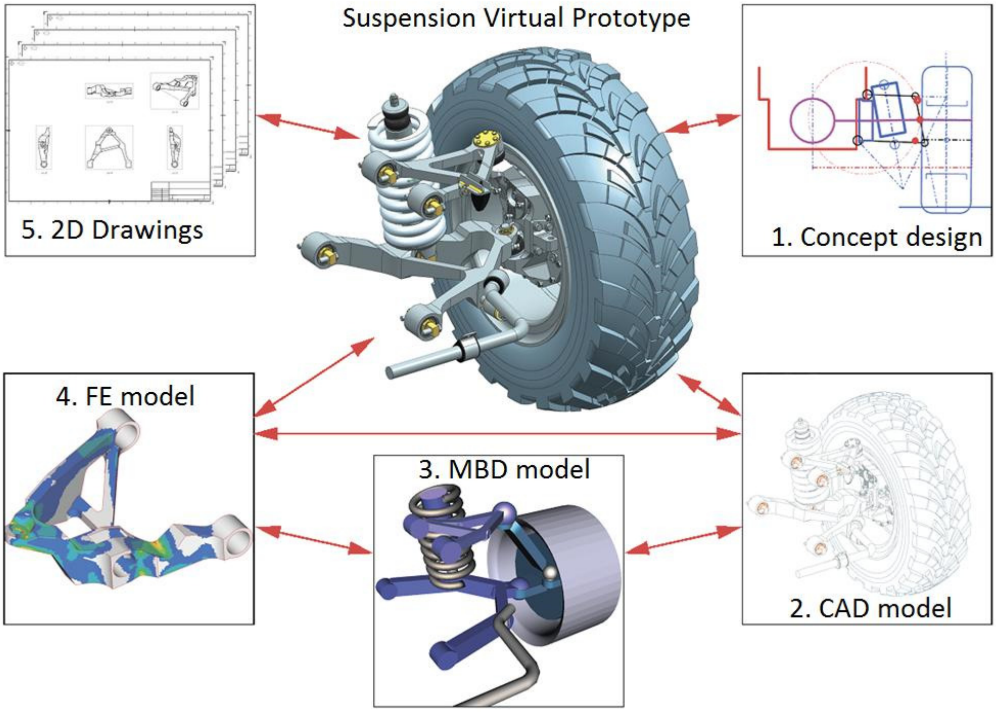

Fig. 1. Suspension development process using virtual prototyping technique

First stage (see fig.1) include suspension concept design, 2d-sketches with kinematics analysis, wheel-to-spring ratio calculations, suspension travel, spring and damping rates calculations. Optimization problem solution, using simplified bar/rod models give engineer geometry of key links: levers lengths, joints and spring/damper attachment point's coordinates and so on.

Second stage (see fig.1) dedicated to elaborative 3d-modelling of every suspension part and wheel-hub drive. Engineer use previous calculations results and similar suspension designs to choose existing standard parts or to formulate requirements for new ones.

Third stage (see fig.1) consists of Multi-Body Dynamics (MBD) model development steps: importing suspension geometry from CAD-model, specifying joint types between links, specifying spring and damping rates, applying forces and moments. Whole suspension MBD-model attaches by joints to fixed in space vehicle body. Loads, acting on suspension, are usually applied in the tire contact patch or in the center of the wheel (see fig 2.).

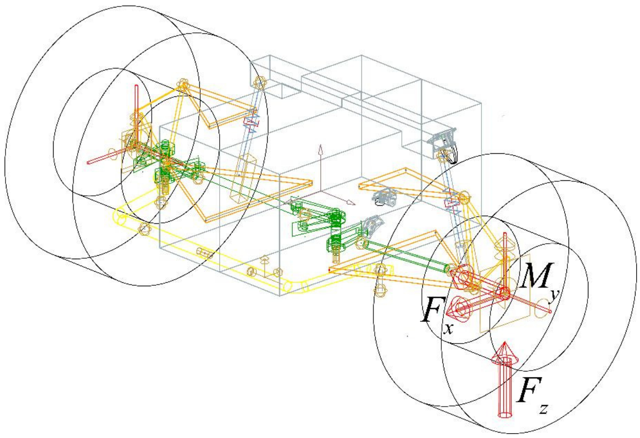

Fig. 2. Double wishbone independent suspension MBD-model with loads

Maximum quasi-static loads in the tire contact patch and/or in the center of the wheel should be calculated from typical vehicle load events. Table 1 shows some typical examples of events for off-road full-drive vehicle.

Table 1. An example of off-road full-drive vehicle load events list for maximum suspension quasi-static loads calculation

Event name
1. Acceleration on a flat horizontal road with maximum traction
2. Acceleration on 60% slope uphill drive
3. Deceleration on 60% slope downhill drive
4. Sidehill slope drive
5. Diagonal wheels hanging with maximum traction
6. Vertical escarpment overcome
7. High-speed cornering with minimum turn radius
8. Brake on a flat horizontal road with specific deceleration
9. Uphill drive with a trailer

Forces in joints determined from MBD-model are necessary for suspension standard parts choice or used as requirements for new parts development.

Forth stage (see fig.1) include stress-strain analysis of suspension parts using finite-elements modelling. Loads, defined on previous stage, transfers to FE-model using tables, graphs and other documents. After FE-analysis, suspension CAD-model should be corrected to fulfil strength requirements.

Engineers must repeat stages from two to four until all requirements – packaging, parts strength, and vehicle integral indicators – are satisfied.

*Fifths stage (*see fig.1) dedicated to 2d-drawings and other technology papers elaboration for suspension construction.

In the described process, the most time is devoted to suspension parts 3d-modelling and packaging, loads calculation and finite-element analysis. To reduce time cost, loads recalculation after every CAD-geometry correction is often neglected, and stress analysis often performs in assumption that loads are not changed. This leads to decreased strength estimation accuracy, even, in worst case, – to wrong strength prognosis, or, at least, to non-optimal mass of suspension due to high margins of safety, and hence – low competitiveness.

To avoid these problems, it is necessary to significantly reduce time costs for loads and stress recalculation. This will allow to perform numerous updates for loads and stresses, up to every geometry change in the suspension CAD-model. To reduce time costs for loads and stress recalculation following actions could be helpful:

- Automate two-way geometry update for MBD-model and CAD-model using key point's coordinates (joints and levers, hub and spring/damper attachment points to vehicle body).
- Automate load transfer into FE-analysis for every suspension part in the key points.
- Automate stress analysis reporting and part strength confirmation.

This automation can be achieved using following techniques:

- Perform simultaneous MBD-modelling (stage 3) and CAD-modelling (stage 2), connecting key-points coordinates for: joints and attachment points of suspension parts (levers, links, rack, wheel-hub and so on).
- Using *provisory* bodies for MBD-model instead of waiting for actual parts CAD-models import.
- Automatically transfer loads to finite-element models for every load event in the key-points and build finite element models, using the key-points as reference points for loads.
- Define mass and inertia properties for *provisory* bodies using designer's experience on first try, and automatically reference to CAD-model mass properties on the next cycles.

3. Conclusions

Presented synchronized building of MBD and CAD automotive suspension models, and automatic two-way update of geometry for this models using key-points (levers, rack, wheel-hub, spring and damper joints), allows to:

- Significantly reduce time costs for cyclic loads and stress recalculation due to frequent geometry update;
- Increase loads and stress simulation accuracy and reliability due to up-to-date geometric initial data;

Double wishbone independent suspension development experience, using presented techniques, shows up to a 10% increased accuracy in loads definition (comparing to simplified beam-rod models with predefined fixed position). Recalculations of loads for specified events were carried out every time, when joints coordinates and attachment points of suspension were changed in the CAD-model. Automated load transfer to finite-element model and automatic finite-element mesh update from CAD-model saved time for optimization problem solution with minimum mass as objective. Closed loads-stress calculation loop allowed to make strength conclusion for suspension's parts using events, excluding elaborative time-consuming work with loads documents (tables and graphs). This significantly reduces amount of information, which stress-analysts and vehicle designers are working with.

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